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An Approach to Force Composition Analysis

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An Approach to Force Composition Analysis

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FOREWORD

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An Approach
to Force Composition Analysis

INTRODUCTION

Within the cycle of planning, programming, budgeting, and implementing of forces, the planning phase emphasizes analysis and synthesis. The subsequent phases emphasize further detailing and review of force plans. Only the planning phase will be discussed in this paper.

The principal product of the force planning phase is a preferred future force and a plan to attain it. It is a force changing over time, representing some estimated effectiveness in time, relative to estimated threats and other uncertainties. To meet stated objectives under assumed conditions and uncertainties alternative forces are given or designed, each having some estimated future effectiveness and cost. The alternatives are existing forces and changes to existing forces. The preferred future force is selected from among the alternatives by applying a criterion that specifies the relation between effectiveness and cost that will result in preference. The design of a criterion for preference is an essential and difficult element of force composition analysis.

MEASURES OF EFFECTIVENESS

The objectives of a force are multiple, diverse, and strongly interdependent with strategic and political considerations. The effectiveness of mixed forces, e.g., corps or divisions, against an opponent is a function of the commander's utilization of the capabilities or effectiveness of the combat and support elements, e.g., brigades or battalions, of the force. The effectiveness of these elements, in turn, is a function of physical performance capabilities and operational use of men and materiel subject to the opponent and the environment.

Elements of the force are substitutable for and complementary to each other in varying degrees. Substitutability and complementarity are not absolute but relative to a given situation. They are among the essential attributes that lend flexibility to the employment of forces by the tactician.

Such quantitative measures of effectiveness as are available for forces are only substitute measures—indicators of effectiveness—measuring some observable capability or effect. The exact relation between such observables and the effectiveness in achieving the objectives defies precise definition but cannot be assumed to be a continuous proportion or other simple function.

Within this limitation, effectiveness measures of combined forces are usually highly aggregated, e.g., rate of advance, index of combat effectiveness, casualties or force ratio. Less aggregated measures are available on the elements of the force. Their effectiveness can be approximately described by measures related to their principal functions and capabilities and can be

reasonably specific with respect to the means or weapons systems of the force element.

It is not now possible to analytically combine the effectiveness measures of the elements of the force into effectiveness measures for a combined force, i.e., mixes of numbers and types of force elements. Conversely, the measures of effectiveness on the combined force cannot be directly applied to the choice among numbers and types of force elements and their principal items of materiel.

The effectiveness of forces, especially of combined arms or mixed forces, cannot be adequately described by any single-valued measure that can be put into a convenient formula relating effectiveness and cost. The dimensions of effectiveness are many; they differ among weapons systems and organizations. Interactions and interdependencies cause measures to be relevant only to a given situation; there is neither proof nor disproof of homogeneity, linearity, or independence. Force-effectiveness functions are not continuous; a force is not divisible into infinitesimal units. Effectiveness measures are not only incommensurable with cost but also with each other. Informed judgment must be employed to compare, integrate, and evaluate the many aspects of effectiveness with respect to the objective.

Recognizing this necessity, analyses can be designed to provide as much relevant quantitative and qualitative information as possible and to sharpen judgment and intuition for the evaluation of the effectiveness of alternatives. This dual function of the analyses, the descriptive and the heuristic, also lends itself to establishing a good working relation between civilian and military analysts and planners.

CRITERIA FOR PREFERENCE

The literal application of economic criteria may not be possible but they are helpful in formulating criterion problems and approaches to their solution. We cannot directly apply the simple rules of profit maximization to select the force that has the greatest positive difference between effectiveness and cost because they are incommensurable—but we tend to think as though we could. We cannot actually find the ratio of incremental cost to incremental effectiveness because we can neither accept as adequate nor define mathematically an unidimensional effectiveness function—but we think in terms of diminishing marginal utility.

In the search for a preferred force alternative we need, however, something more than subjective utility functions. Analytical comparison of alternatives at the same effectiveness and selection of the lowest cost alternative or comparison at the same cost and selection of the highest effectiveness alternative have become accepted criteria for preference. The equal-effectiveness lowest-cost criterion has been frequently employed in the analysis of weapons systems; the equal-cost highest-effectiveness criterion has been employed in Army division, corps, and theater force studies. In either case, the costs are peacetime costs estimated for some period in the near future.

An extension of the criterion of highest effectiveness at equal cost is believed to be of interest for Army force composition analysis and resource planning. In this extension the effectiveness of alternative combinations of

force elements is compared at the same total cost and manpower levels to develop a criterion of preference.

The equal manpower constraint is introduced in addition to the equal cost constraint, because using only costs as a measure implicitly assumes complete factor substitutability. This assumption is not representative of military resources. The manner in which military manpower is reflected in costs does not adequately represent the relative scarcities of personnel and materiel. Military pay is not determined in a competitive labor market. Numbers of military personnel are limited by statute. It is conceptually possible to compensate for these discrepancies by shadow prices on military personnel but this technique is quite difficult to implement.

For the purposes of the analysis, we will use the concept that for any given level of manpower there is a minimum cost force, representing the basic, infantry-type equipped and skilled combat elements and their support. Substitution of more expensive materiel and more complex skills results in higher cost at the same manpower level. It also affects the proportion of combat to support personnel. This is a form of capital investment to increase the effectiveness of manpower. One would like to apply the conceptually similar productivity and profitability criteria but incommensurability makes that impossible in a strictly quantitative manner. Manpower- and cost-level constraints can be used, however, to analyze the effectiveness of relative quantities of materiel as an aid in planning decisions (for some planning problems, other constraints may be more stringent and therefore more appropriate; for example, weight or volume per unit of time could represent tight deployment or logistic constraints for given distances).

In order to gain insight into the effectiveness of mixed forces and into the problem of determining quantitative requirements for different weapons systems and materiel it is useful to compare preferences among alternative forces, synthesized from force elements that represent men and materiel in an analytically consistent manner. Marginal substitution of force elements under an equal input constraint on the force alternatives provides indicators for the analysis of the marginal effectiveness contribution of force elements to the effectiveness of the force. The descriptive analysis that will be discussed is designed to aid the subjective integration of the diverse components of effectiveness. The equal manpower and cost constraints limit the subjective evaluation to a preference ordering of the alternatives according to their effectiveness.

MODELS

In order to relate the effectiveness of a force to the effectiveness or capability of each of the diverse types of elements of the force and relate these, in turn, to manpower and cost it is convenient to visualize a structure of several interlocking types of models: a force effectiveness model, a force element effectiveness model, a system and organization model, and a cost model. These types of models are mainly logic models, i.e., they serve to formalize and structure relations among the many different components of a cost-effectiveness analysis. Some of these formal relations can be further defined in mathematical terms, computer programs, simulations, or other forms.

A force effectiveness model serves to relate the one or more measures of effectiveness on the force to one or more measures of effectiveness or capability of each force element in the context of a campaign.

A force element effectiveness model relates one or more measures of effectiveness or capability of an element of the force to measures of performance in the context of an operational environment and use.

A systems and organization model relates the measures of performance to the physical specifications, quantities, and activity rates of all resources required to generate this performance in an organizational context.

A cost model relates the physical specifications, quantities, and activity rates to measures of cost through factors and estimating relations.

The rationale underlying this structure of models is very simple; it is intended to separate the additive from the nonadditive and the at least partly linear from the completely nonlinear aspects of the analysis and to provide a transition and link between characteristics of a problem that, although always multidimensional, differ markedly in type and number of dimensions.

At the force element level typical tactical objectives are selected for more detailed analysis of the functions to be performed. The dimensions of effectiveness or capability are identified: those for which quantitative measures can be obtained and those that must be described qualitatively. Measures of effectiveness and interactions to be modeled are selected and the necessary submodels designed. The one or more effectiveness measures and submodels for a type of force element can only partly describe its capability; narrative must be employed to fill in gaps and highlight uncertainties, assumptions, and sensitivities. Effectiveness models describe processes and interactions; flow diagrams are a basic descriptive tool and may be supplemented by mathematical functions, simulations, or other quantitative techniques.

From each of the effectiveness submodels performance measures are derived that describe the physical output of men and materiel as a system in an organization; it operates and supports the system consistent with its operation concept. Because of the breadth of scope of a force composition analysis, weapon system characteristics must be taken as given; it is simply not practical to search for the optimal tactical observation aircraft design while searching for a preferred force. Individual weapons systems and items of materiel must be assumed to be best choices of previous selection processes. One can, of course, hypothesize weapon system characteristics of a more advanced type or performance in the analysis to gain insight into their impact on force effectiveness. Again, however, the hypothetical weapon must be taken at an assumed or given set of characteristics.

The detailed analyses of the effectiveness models identify physical resources in a process. In the system and organization model, they are ordered into a logically designed functional organization. From this structure the physical specifications, quantities, and activity rates of all required resources can be tabulated. The manpower totals, including the support requirements, are derived from this model.

One or more cost submodels relate the physical resources to costs through estimating relations and factors. Such costs need not be precise in an absolute sense; they are used in a relative manner. Completeness and consistency are of primary concern, as is reflected in the preceding steps of the analysis. A

detailed discussion of military cost analysis is not within the scope of this paper. Some aspects of cost are, however, of particular interest here and will be touched on briefly.

COSTS

Costs that are of interest to the planner are, of course, only those to be incurred for each alternative; past expenditures are not relevant to the criterion of preference. Recurring and nonrecurring costs are separately identified. Generally, only peacetime costs are estimated; for certain problems incremental wartime costs may also be shown, although not necessarily added to the peacetime costs. Where cost-quantity relations are not linear, e.g., for materiel such as aircraft, it is necessary to generate a cost schedule from which costs appropriate to a given or assumed quantity can be selected.

Future costs of weapon systems or force elements that are physically feasible alternatives during the same time period and that have approximately the same useful life expectancy are usually summed over some arbitrary period of time ranging from 5 to 10 years. The effectiveness of the alternatives is estimated at a point in time falling within that period. The convenience of dealing with fewer numbers as a result of summation of cost streams does, however, introduce some problematical assumptions. To merely sum the future costs is equivalent to applying a zero rate of discount. Should a positive rate be used? How is it to be determined? Should all components of costs of the alternatives be discounted, and if so, at the same rate? There are no immediately obvious answers to these questions; sensitivity analysis can illuminate them, for example, by indicating what discount rate would need to be assumed to cause a change in preference.

SELECTION OF PREFERRED ALTERNATIVE

The analysis of effectiveness and cost of each force element described in the discussion of the model structure leads to a "catalogue" of force elements. In this list, each type of element is appropriately identified with respect to its effectiveness or capability, its manpower, and cost. Because the support requirements of each type of force element are included, different types and numbers of elements can be conveniently added to form a force; their manpower and cost subtotals can be added separately to obtain force totals for manpower and cost.

Having generated a set of additive elements with which to structure a force, we can now turn to their nonadditive effectiveness. As discussed earlier the criterion problem here is to select a preferred alternative force, thereby selecting quantities and types of force elements. The alternative forces should have the same manpower and cost so that they can be ranked ordinally on the basis of effectiveness alone.

For an assumed or given constraint on manpower and cost taking, for example, the existing force as the base case, alternative combinations of force elements for, say, strategic or contingency plans are selected manually or with

computer assistance. Several redesigns consisting of substitutions of force elements at the margin may be desirable to refine a reasonable number of distinct alternative force concepts. The equal-input force alternatives so designed are evaluated with the aid of the force effectiveness model mentioned earlier in the description of the model structure. In this model the measures of effectiveness of the force are related to the effectiveness or capability of the selected force elements in campaigns by simulation, quick war games, or other appropriate interaction models. The design of the opposing force should allow for reasonable responses to the friendly configuration.

As a result of insights gained in the interaction model, iterations of this sequence of force syntheses and analyses may be desirable to design and examine additional force configurations. The analysis may be repeated with different constraints to obtain indications of the sensitivity of the force effectiveness to quantitative considerations.

As discussed earlier in this paper, measures of effectiveness of the force that are currently available are highly aggregated. A combination of analytical skill and military experience, and of quantitative and qualitative evaluation and judgment is required to assess the estimates of relative effectiveness of force alternatives modeled.

Quantitative and qualitative information about outcomes, campaigns, contingencies, and friendly and opposing forces can be organized and displayed in a manner similar to setting up a game-payoff matrix but no game solution will be sought in a formal sense.

The equal-input constraint on the alternatives concentrates the evaluation on their relative effectiveness. The analysis of the causal relation between force elements and force effectiveness is aided by the identification of those force elements that are peculiar to the alternatives. The preferred force configuration serves to indicate the relative marginal effectiveness of force elements and aids in the planning of relative quantities of different types of materiel. In the subsequent steps of the planning phase the feasible time-phased plans for achieving a preferred force are developed.

The approach to force composition analysis discussed in this brief paper has been partly applied in studies and found to be helpful. Work is currently in progress to refine models and factors to increase the accuracy of estimates and decrease the time required for analysis.